

Chapter 4 : Digital Satellite Downlink Reception

The AFRTS signal is a digitally compressed MPEG signal and as with any digital signal there is perfect reception or nothing at all. Tuning to an MPEG compressed digital signal, however, is a little different from tuning to a standard analog signal. Weak signals appear to be random noise; the receiver will not display any picture at all until sufficient signal is reaching the antenna. Then, once the digital threshold of the receiver/decoder is exceeded, a perfect picture will appear on the TV screen. MPEG digital reception is like a light switch; it's on or off. This is to say that a digital signal has two states, perfect (on) picture quality and reception or nothing at all (off). Furthermore, if the installer moves past the antenna's peak performance position, the picture will "freeze frame" on the last picture in its buffer memory. The IRD will not receive any further video until the antenna is repositioned to receive a signal above minimum receiver threshold. Peaking the signal improves the overhead above threshold and ensures a good picture under poor weather conditions.

Typical Satellite TVRO Equipment Configuration

The typical equipment arrangements used to receive AFRTS services are provided at Figure 3-2. Specific equipment requirements for receiving AFRTS services are provided in the section titled Qualification of Satellite Terminals or Digital Reception.

General Satellite Concepts

The concepts underlying satellite broadcasting are straightforward: signals beamed into space by an "uplink" dish are received by an orbiting satellite, electronically processed, re-broadcast or "down-linked" back to earth and then detected by a dish and associated electronics. A receiving station can be situated anywhere within the satellite's "footprint" (see Chapter 3, satellite footprint maps). The overwhelming strength of satellite broadcasting lies in its ability to reach an unlimited number of sites regardless of their location without the need for any physical connections.

Nearly all communication satellites designated for commercial use are positioned or "parked" in the "Clarke Belt", also known as the "geostationary" arc. The Clarke belt lies in the equatorial plane 22,300 miles above the equator. This circle around the earth is unique because in this orbit the velocity of a spacecraft matches that of the surface of the earth below. Therefore each satellite appears to remain in a fixed orbital slot in the sky above. This allows a stationary dish to be permanently aimed towards a targeted geostationary satellite.

A satellite receives the up-linked signal, lowers its frequency and re-broadcasts it to any chosen geographic area. Downlink transmit antennas can target over 40% of the earth's surface with "global" beams, can broadcast to selected countries or continents via "zone" beams, or can pinpoint smaller areas with "spot" beams. Many domestic C-band broadcast satellites direct one beam that blankets the continental U.S. and a second more localized one to the Hawaiian Islands. Ku-

band satellites, operating in the higher frequency 12 GHz range, are configured for spot beams and require smaller antennas to receive their signals.

The Receive Site

At the receive site a dish reflects and concentrates as much of the very weak down-linked signal as possible to its focus where a feed channels the signals into the first electronic component, the low noise block converter (LNB). The signal is then cabled indoors to the satellite receiver and processed into a form that can be deciphered by a television, stereo or computer.

Radio Waves and Communications

The transmission of extremely low power microwaves, a form of radio waves, underlies the operation of radio, conventional television, satellite broadcasting and other man-made communication devices. They are one form of more general phenomena known as electromagnetic waves that travel at the speed of light, equal to 186,000 miles per second. At this rate, a signal travels from the uplink, to a satellite and back again to earth in about 4/10ths of a second.

Radio Waves

Radio waves are defined by their frequency, power and polarization. These parameters are briefly discussed below.

Signal Frequency

The frequency of a radio wave is the number of vibrations that occur every second. Just like the frequency of sound vibrations determines whether a musical note is either a soprano or a bass, so the frequency of radio wave determines whether they are used to transmit regular AM radio broadcasts or satellite television broadcasts. Microwaves have frequencies in excess of one billion cycles per second (known as one gigahertz and abbreviated 1 GHz) to as high as 50 GHz. C and Ku-band satellite downlink signals fall in the 4 and 12 GHz range, respectively.

Polarization

Radio waves can be polarized. Two standard formats commonly used in C and Ku-band satellite communication links are linear and circular polarity.

Linearly polarized signals can have either vertical or horizontal polarity. In this case, the electric and magnetic fields of the signal remain in the same planes in which they were originally transmitted. Horizontally polarized waves vibrate in a horizontal plane; vertically polarized waves vibrate in a vertical plane. Most C-band signals broadcast to TVROs (television receive-only) are linearly polarized.

In circularly polarized signals the electrical and magnetic fields rotate in a circular motion as they travel through space, somewhat analogous to a spiral. The direction of the rotation determines the type of circular polarization. A signal rotating in a right-hand direction is termed right-hand circular polarization (RHCP)

and a signal rotating in the left-hand direction is termed left-hand circular polarization (LHCP).

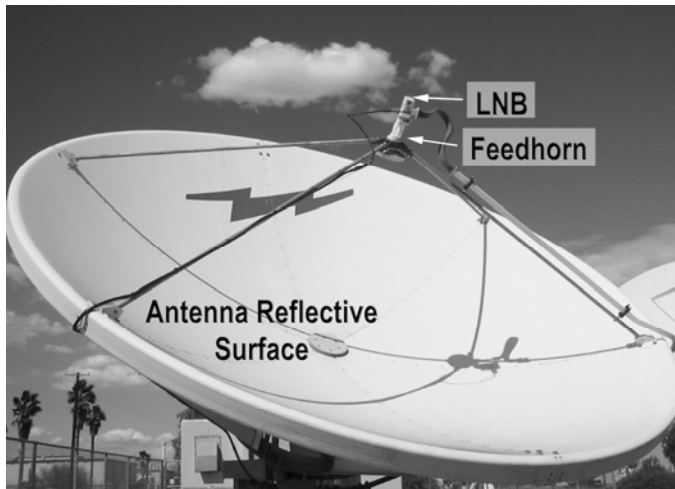


Figure 4-1 Satellite dish parts

A principle advantage of circular polarization is the elimination of the need for skew adjustment. A feed designed to receive a linearly polarized signal must be correctly lined up with its plane of polarization to allow reception of the highest possible power and therefore clearest picture. It requires a skew adjustment for fine-tuning. However, a feed that receives a RHCP or LHCP signal can be attached at the focal point of the dish in any

orientation.

There are three noteworthy components of a satellite receive antenna which collectively capture and amplify the signal to a level large enough to break the receiver reception threshold, normally around negative 45dB. These are the reflective surface or parabolic curvature, the feedhorn and the amplifier section “Low Noise Amplifier (LNA), Low Noise Block converter (LNB), Low Noise Converter (LNC), and Low Noise Feedhorn (LNF). We will focus on these areas because they are the components that we personally come in contact with and have the greatest control over.

Antenna Reflector

The reflective surface in a perfect world would rely on the geometric properties of its true parabolic curve to reflect the satellite signal to a very sharp focal point. The focal point on a parabolic antenna is out in front and to the center of the surface. This would be a well-defined area if a perfect parabolic curve were defined, however this isn’t as defined as we would prefer. The focal point is not as perfect as theory would dictate but is still within a small radius and is a defining difference in a perfect or marginal signal reception. This you may say is where the “rubber meets the road” and collection of the signal is critical in this area.

Reflective surfaces come in several different shapes and sizes but are most common in the parabolic or offset shape. Offset shaped antennas are nothing more than a small section of the original parabolic antenna see figure 4-2. The larger the reflective service the better defined the focal point becomes and therefore more gain can be expected. The reflector sometimes mistakenly called the antenna is the first step in a well-engineered system that will continue to



Figure 4-2 An offset satellite antenna

provide service under harsh environments. If the size of your dish is too small for the signal you intend to capture, nothing is going to compensate for that. Working with an analog signal you could get by with a smaller dish but suffer with a noisy picture. A digital signal on the other hand is perfect or nothing situation and with a marginal or less reflective surface you can expect nothing.

Many of the small aperture Ku-band dishes sold these days use an offset antenna, see figure 4-2, a feedhorn design which places the focal point below the front and center of the dish. This type of antenna, as defined earlier is actually a small oval subsection from a

much larger parabolic antenna design, is oval in shape with a minor axis (left to right) that is narrower than its major axis (top to bottom). Because of its unique geometry, the offset fed antenna requires a specially designed feedhorn, which matches the antenna geometry precisely. For this reason, the offset fed antenna and feedhorn are usually sold together as a single unit. This type of feed is called a Low Noise Feed or LNF.

Amplifier “LNA/B/C/F”

The concentrated signal from the reflective surface is channeled to a low noise amplifier that has a very low noise floor. The job for this section is to amplify the signal to a level that is above the receiver’s threshold. The Low Noise Amplifier (LNA) amplifies the signal at the output of the earth station’s antenna. The most commonly used LNAs use gallium arsenide field effect transistors (GaAsFETs). Typical noise temperatures of amplifiers produced today range from 15° K to 60° K (LNB\C\F).

The LNA is a weather sealed unit that provides enough gain to transport the signal from the antenna to the receiver. It is located as close the feedhorn as possible to minimize signal loss and thereby improving signal to noise ratio. The problem with an LNA is that the signal is in several gigahertz frequency range and requires expensive transmission lines to carry the signal from the antenna to the receiver. A much more efficient way of doing this is to down-convert the signal at the antenna to a lower frequency for transmission to the receiver. This is accomplished with the newer LNB/C/F to lower the satellite normal GHz frequencies to an L-band frequency between 940 MHz to 1450 MHz. For ease of discussion, all Low Noise Amplifier types will be referred to as a LNB, from this point forward

There is a basic tradeoff between LNB noise temperature and antenna size, which is gain, expressed by the system figure of merit G/T. Smaller antennas require a cooler LNB temperature for equivalent system performance. Whereas a larger antenna allows use of an LNB with a higher noise temperature. This should not be misunderstood and you should not be misled that an amplifier with a lower noise temperature will correct for any antenna size. G/T is a measure of the ability of a receiving system to amplify very weak signals, such as those of a satellite transmitter 22,300 miles away over the background noise. The "G" is antenna gain and the "T" is its noise temperature. The job for the LNB is to overcome this noise figure with a carrier to noise C/N separation of greater than 8dB, see Spectrum Analyzer plots. The average for reliable reception of the AFRTS digital signal is 12dB of signal above the noise floor. It should be noted also that a digital signal reacts to noise and interference differently than a analog signal. Noise or interference introduced in a digital environment will cause pixelization and even loss of signal reception. Whereas in the analog world, received video will have noise or sparkles but in most instances would not suffer total loss of signal. The advantage of the digital signal is, there is no change in the signal quality until it deteriorates below the receiver reception threshold. But, at that point the received video will go from perfect to total loss of signal; notice there is no in between.

The noise figure or temperature, expressed in decibels or degrees Kelvin, respectively, is a measure of the degree by which this amplifier degrades or decreases the signal-to-noise ratio of the satellite signal as it passes through the device. This scale is based on the fact that at a temperature known as absolute zero, 0° K (equal to minus 273.16° C or minus 459.72° F), molecular motion ceases and consequently all electronic noise disappears. The lower the noise temperature or figure, the better amplifier performance. There are amplifiers on the market today with noise temperatures as low as 15°. Getting below 15° K, requires external cooling of the electronics and is a very expensive endeavor.

Gain is also very important in characterizing low noise amplifiers. The more common LNB gains today usually range from 60 to 70 dB. LNBs must be designed with sufficient gain to overcome cable losses as well as the effects of noise contributed within this device and overall system noise temperature.

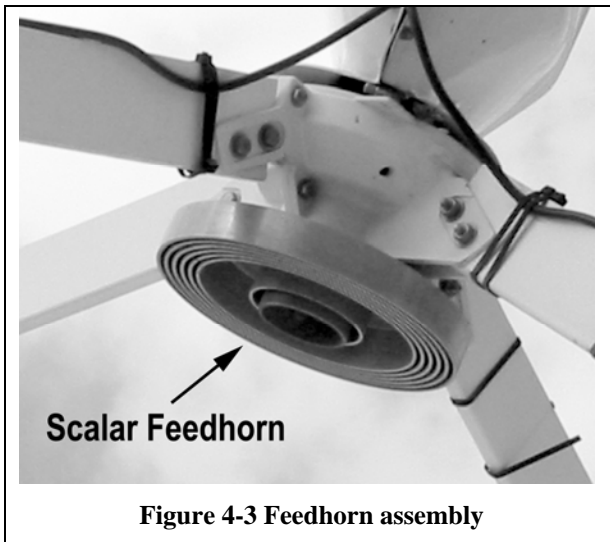
The low noise block down converter, the LNB, detects the signal relayed from the feed, converts it to an electrical current, amplifies it and down-converts or lowers its frequency. LNBs in both analog and digital systems down-convert the signal to a band in the 950 to 1450 MHz range. The “down-converted” signal is subsequently relayed along cable to the indoor satellite receiver.

Signals reaching the input of an LNB from a typical 8-foot C-band dish have powers of less than 10^{-14} watts/m². Therefore, an LNB must contribute very little noise power or received satellite signals will be drowned out in the roar of amplifier internal thermal noise. This feat is made possible by advances in transistor technology. Without such progress, satellite broadcasting would not exist as we know it today.

LNB Performance

There are three specifications that affect the performance of the LNB and have a direct effect on the ability of a system to satisfactorily capture a satellite signal. In order of importance for digital reception is, the noise temperature, Local Oscillator stability (L.O.), and its gain expressed in dB. The noise temperature of the amplifier must be low enough to overcome the noise floor of the antenna to a minimum of 8dB above the signal to noise floor.

Feedhorn Assembly



Feedhorns, as with the reflective surface also come in several different forms with the most common being the scalar feedhorn. The scalar feedhorn has a large circular plate with a series of circular rings attached to its surface, see figure 4-3. These rings collect the signal at the antennas focal point and conduct the incoming signal to the waveguide attached between the rings and the LNB. The effect of the scalar rings is to concentrate the signal in an effort to correct the imperfections of the parabolic shape. Therefore the effect of the feedhorn

to focus or channel the incoming signal is critical in signal reception. Adjustment of the feedhorn will be discussed later but is a must to take advantage of the systems overall gain and therefore reducing the overall system noise floor.

The scalar feedhorn primarily sees or is illuminated by the inner portion of the antenna's surface area, while attenuating the signal contribution from the outer portion of the dish by 8 to 22 dB, depending on whether the dish is deep or shallow in its construction. Molecular motion within the Earth itself generates random noise, which permeates the entire electromagnetic Spectrum used for

the transmission of satellite signals. This random noise is many times stronger than the satellite signals reaching any location. The attenuation or illumination taper provided by the feed sharply reduces the reception of the Earth noise which lies just beyond the antenna's rim. The outer area of the antenna's surface therefore acts more as an Earth shield for the feedhorn than as a contributor to the overall signal gain of the receiving antenna.

Feedhorn Adjustments

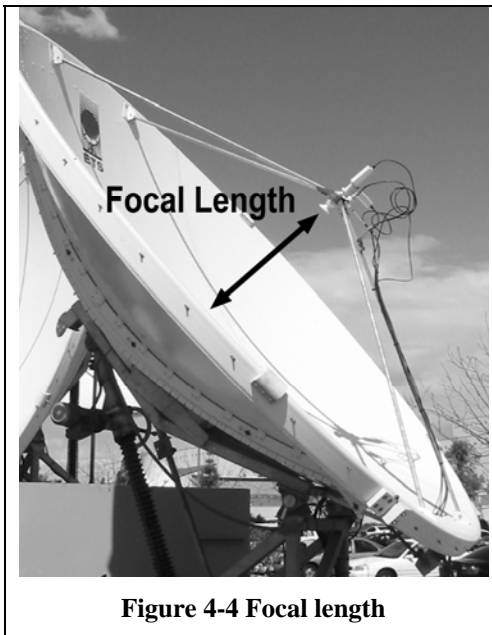


Figure 4-4 Focal length

Focal length between the center of the antenna surface hub and bottom of the feedhorn assembly facing the antenna surface should be initially set to the distance recommended by the antenna manufacture, see figure 4-4. Adjustments of 1/8 inch or more in or out from the recommended distance should be made while using a signal meter or Spectrum analyzer to determine the precise position required for maximum signal acquisition. This is particularly important for antennas composed of individual segments, especially those composed of mesh panels as antenna surface irregularities due to careless antenna assembly can actually shift the optimum position of the focal point from the value recommended by the antenna manufacturer.

When adjusting the feedhorn in or out, be sure that the waveguide opening remains precisely centered over the dish at all times. You can check this by measuring from the antenna's rim to the outer ring of the waveguide opening from four equidistant positions around the rim. All of these measurements should be equal.

There is an important difference in the process of aiming an analog and a digital dish. When even a faint signal is received a hint of a television picture appears with a conventional TVRO. Then fine adjustments can be made to improve reception. A digital system either acquires the signal or nothing. Therefore the aiming angles should be set as accurately as possible before powering on. Once the signal has been acquired, then the signal strength can be monitored for fine-tuning. One saving grace with small dish systems is that the beam width is so wide that aiming errors of even a degree or more will not have a major impact. While fine-tuning the digital dish monitoring the signal strength is a good indication of raw RF, but as a word of caution, don't sacrifice BER for signal strength.

Polarization

There are four polarities most common to communications satellites in orbit today. These are horizontal, vertical, left and right hand polarization and your system pickup probe must be aligned accordingly for best reception. There are several different types of feeds: some will need to be manually polarized and some will not depending on the type of feedhorn used. This adjustment is best accomplished while monitoring the satellite signal on the display of a spectrum analyzer. If a spectrum analyzer isn't available, make this adjustment and maximize the BER of the receiver. Rotate the feedhorn until you begin to see the other polarization. Turn your receiver on and look at the BER. You will notice that it gets worse as the other polarity begins to increase. The idea is to minimize the other polarization and at the same time maximize the BER or signal quality of your receiver. If you notice that rotating the feedhorn in a 360° rotation makes no difference to the BER/Signal quality. This indicates that your feedhorn is not adjustable and is factory set to the polarization of the satellite transponder and no further adjustments are necessary.

Qualification of Satellite Terminals for Digital Reception

The following three subsections include lists of equipment needed to receive the AFRTS signal. The boxes cover equipment for SATNET C-band, SATNET Ku-band and Television-Direct to Sailor (TV-DTS) C-band digital reception.

Equipment needed for SATNET C-band reception

1. Dish Size: 4.5 meter (minimum size)
2. Mid-band Gain: 43.6 dBi
3. Feedhorn
 - 3.1. For Domestic Region (IntelSat Americas-5) C-band Linear Vertical Polarization (V)
 - 3.2. For Atlantic Ocean Region: C-band Right Hand Circular Polarization (RHCP)
 - 3.3. For Pacific Ocean Region: C-band Left Hand Circular Polarization (LHCP)
4. Low Noise Block (LNB)
 - 4.1. Noise Temperature: 25° K (+ -) 5° K
 - 4.2. LO Stability: 1,000 kHz (+ -) 100 kHz
 - 4.3. Recommend using a NORSAT Model 8525F
5. Cable: RG-6 or RG-11
6. L-band Splitter: Caution terminate all unused ports
 - 6.1. Must be diode steerable, power passing on all legs
 - 6.2. Recommend using a Channel Master 1x4 Model. 24141FD

7. L-band in Line Amplifier

7.1. 20dB gain from .9 ~ 1.75 (GHz)

7.2. Recommend using a DX Antenna Model ES-25

8. R.F. Connectors

8.1. For RG-6, recommend using Anixter P/N 144017

8.2. For RG-11, recommend using Anixter P/N 095178

Equipment needed for SATNET Ku-band reception

1. Dish Size: 80 centimeters to 1.5 meter (For the size needed in your location, refer to the satellite footprint maps in chapter 3, figures 3-6 for Japan and Korea or figure 3-7 for Europe.)

2. MidBand Gain: 80 CM 37.6 dBi

MidBand Gain: 1 meter 39.5 dBi

MidBand Gain: 1.2 meter 41.7 dBi

MidBand Gain: 1.8 meter 44.5 dBi

3. Feedhorn Ku-band Linear Vertical Polarization (H)

4. Low Noise Block (LNB)

4.1. Noise Temperature: 0.6 to 0.8° dB

4.2. LO Stability: 750 kHz (+ -) 100 kHz

4.3. Recommend using a NORSAT Model 4708C

5. Cable: RG-6 or RG-11

6. L-band Splitter: CAUTION TERMINATE ALL UNUSED PORTS

6.1. Must be diode steerable, power passing on all legs

6.2. Recommend using a Channel Master 1x4 Model 24141FD

7. L-band in Line Amplifier

7.1. 20dB gain from .9 ~ 1.75 (GHz)

7.2. Recommend using a DX Antenna Model ES-25

8. R.F. Connectors

8.1. For RG-6, recommend using Anixter P/N 144017

8.2. For RG-11, recommend using Anixter P/N 095178

Equipment needed for Direct to Sailor (DTS) C-band reception

1. Dish size: 1.2 meter

2. MidBand Gain: 43.6 dBi

3. Feedhorn C-band Left Hand Circular Polarization (LHC)
4. Low Noise Block (LNB)
 - 4.1. Noise Temperature: 20° K (+ -) 5° K
 - 4.2. LO Stability: 500 kHz (+ -) 100 kHz
 - 4.3. Recommend using a NORSAT Model 8520C or California Amplifier Model 140194.
5. Cable: RG-6 or RG-11
6. L-band Splitter: CAUTION TERMINATE ALL UNUSED PORTS
 - 6.1. Must be diode steerable, power passing on all legs
 - 6.2. Recommend using a Channel Master 1x4 Model. 24141FD
7. L-band in Line Amplifier
 - 7.1. 20dB gain from .9 ~ 1.75 (GHz)
 - 7.2. Recommend using a DX Antenna Model ES-25
8. R.F. Connectors
 - 8.1. For RG-6, recommend using Anixter P/N 144017
 - 8.2. For RG-11, recommend using Anixter P/N 095178

Some New Terms You Should Know and Understand

Moving into the new digital age will require a basic understanding of a few new terms that make up this new technology. The following is a brief explanation of some of the new digital acronyms and language that you will come across and need to understand.

- (1) **Receiver/Decoder Threshold:** Unlike traditional analog Receiver/Decoder, where the unit continues to deliver a picture even when it is operating below the receiver/decoder threshold, digital systems will not operate below their minimum threshold. The difference being, in the analog world the picture quality will deteriorate from crystal clear, to noisy (sparkles) without total loss of picture. The digital receiver will not show signs of weakened signals and it will have a digital cliff where the signal is no longer processed and is discarded. Therefore, you cannot rate the quality of the signal by comparing it with how good the video is, it's always the same above the threshold.
- (2) **Bit Rate:** This is the amount of data information being transmitted in one second of time. The total stream passing through a single satellite transponder consists of as many as ten TV services and associated audio, auxiliary audio services, conditional access data, and auxiliary data services such as teletext. The informational bit rate for this transmission may be as high as 49 mega (million) bits per second (Mb/s) over a 36 MHz satellite transponder. Single video signals within this bit stream will

have a lower bit rate. For example, a VHS quality movie can be transmitted at a bit rate of 1.544 Mb/s (T-1); general entertainment program at 3.0 Mb/s; live sports with a lot of motion at 4. or studio quality at a rate of more than 8 Mb/s.

- (3) **Bit Error Rate (BER):** Measured in exponential notation, the BER expresses the performance level of the digital receiver. For example, a lower BER of 0.0 E-6 is superior to a BER of 1.0 E-3. The lower the BER, the greater the receiver/decoder's ability to perform well during marginal reception conditions, such as during a heavy rainfall or wind gusts. Depending on which model of Scientific Atlanta Integrated Receiver Decoder (IRD) being used, the quality of the received signal is represented in BER or a signal quality scale of 1-10; 10 being the best. The 9223 will represent signal quality in BER and the 9234 set-top measures quality on a scale of 1 to 10.

Sun Outages

A sun outage is similar in behavior to a rain fade. The high energy level and broadband nature of the sun's energy can overpower a satellites downlink signal and effectively wash out a receive signal with noise. This problem is technically impossible to overcome at this time.

Due to the angle of the sun in relationship to the satellite, a sun outage is actually a mixture of degraded receive performance with the possibility of a circuit outage. A circuit outage might be typically 20% of the total predicted sun outage duration period. Many factors influence how robust a receive circuit may be, therefore it is extremely difficult to predict exactly how long an outage might possibly be. The digital nature of the AFRTS signal means that you'll either have very good signal or none at all with very short periods of degraded "pixilated" signal.

At certain times of year, approximately one month either side of the spring and autumn equinoxes, there may be a conjunction of the sun and satellite positions. Depending upon the size of the earth station antenna, such events can lead to a serious impairment of the space-earth link.

The outages typically last only a few minutes at a time once a day with a normal worse case outage of about ten to fifteen minutes. Outages will affect each link in multi-hop circuits. For example viewers in Europe or the Indian Ocean area would be affected by an outage of first, the Atlantic satellite and then secondly, of the actual satellite feeding their antenna.

Antennas should not be adjusted or re-pointed at these lost-of-signal times. The viewer should wait out the outage until the sun finishes passing directly behind the satellite.

RF Interference in Digital Networks

The transmission of digitally compressed video over satellite allows many high quality video signals to be transmitted in a satellite transponder, which formerly could accommodate only a single high quality video signal. The "compression" of

these services into a narrow bandwidth causes some inevitable trade-offs in the complexity of both the transmit and receive earth stations. Transmit earth stations must be equipped with tremendously complex video “encoders” which digitize and compress the large amounts of video and audio information into a much smaller bandwidth. Receive earth stations must be compatible with the reception of a wide band digital carrier. While most Television / Receive-Only (TVRO) earth stations are compatible with the digital video technology, some will be susceptible to Radio Frequency Interference (RFI), sources which were not significant with analog video transmissions.

In the traditional analog world, interference was spread across a much broader information base where individual elements of information were less critical. With digital compression, much more information is transmitted in a compressed format, which increase the importance of each “Information packet”. Digital compression signals react differently to problems caused by RF Interference in the RF (Radio Frequency) path as compared with traditional analog video signals. Where RF Interference caused either a white line, sparkle or “hum” bar in the Analog video realm, in the digital domain it can result in digital artifacts such as “blocking” and/or a “black screen” or “freeze frames” depending upon the magnitude and duration of the interference and the concealment algorithms used.

TVRO sites experiencing RFI do not always experience any observable effects. A typical transponder operating with a compressed digital video signal may contain up to 8 television programs. Although one might expect each of these signals to be 8 times as susceptible to RFI as a traditional analog signal; in practice the signals are of a higher quality (for a given antenna size) than traditional analog transmission due to the sophisticated error correction and concealment algorithms employed.

Much has been learned about the cause and mechanics of many external interfering sources that enter through the antenna and associated subsystems. This paper will help identify potential origins of RF Interference in addition to providing methods of reducing the effects of interference on the satellite carrier. While it is impossible to eliminate RFI, there are ways in which to both reduce the level of interference and conceal the event so that it has the least amount of perceived effect on the video.

We will address two major interference scenarios, which may be caused by a number of ground-based sources. These sources and their method of interaction with a typical receive terminal are explained. Several methods of reducing the interference and its effects are also explored.

The two types of RFI encountered are Destructive Interference (DI) and Out of Band Interference (OBI). Destructive interference is encountered when the desired receive signal is completely overwhelmed, or disrupted, by an interfering signal (or noise source) in the channel of the desired signal, and at a level equal to or greater than the desired signal. Out of Band Interference is defined as a signal (or noise source) which does not interact directly with the desired signal,

but interacts with other components of the receive system such that the desired signal is impaired or destroyed. Both DI and OBI may originate from the same sources. An interfering carrier from a terrestrial microwave system may act as DI on a carrier at one frequency, and an OBI on carrier at another frequency at the same TVRO site.

Current Technology

Digital video compression receivers differs from traditional FM video receivers in that they receive video and audio signals that are digitized, compressed and modulated using Quadrature Phase Shift Keyed (QPSK) digital modulation. This technique allows the transmission and reception of several high quality video channels and associated audio in a 36MHz transponder. In comparison, traditional analog FM modulation provides only one video and its associated audio signals to be transmitted per transponder.

Error Correction

Because of the increased capacity attained using digital compression and transmission, special error protection is used to either correct errors or provide concealment when the error rate exceeds the capability for the decoder to provide complete correction. To detect and correct errors caused by thermal noise, a technique called soft decision convolutional decoding is used. The IRD and associated up-link equipment use a convolutional encoder to provide error correction to thermal noise down to about 7 dB C/N. Also, to protect against burst noise interference, a special data interleave and Reed Solomon block decoder are used. The combination provides error correction to burst interference outages that can be caused by engine ignition noise, industrial microwave oven interference, and adjacent band interference from such sources as aircraft radar altimeters.

Because there may be instances when the error rate is high enough so that not all errors can be corrected, the IRD contains sophisticated software algorithms that provide image concealment for small-uncorrected errors, and either freeze frames or black-frame substitution for larger uncorrected errors.

The FM Analog equivalent to digital errors is the well-known “white line” or “sparkles that appears on the TV screen when the received signal level drops below the FM threshold of about 10dB C/N. Unlike analog transmission where the “white lines” or “sparkles” are superimposed on the video, uncorrected digital errors can create a loss of digital synchronization resulting in outages that can last longer than the actual duration of the interference. It is during these instances that image concealment is important. Typically, instead of a single “white line” or “sparkle”, a digital error can result in the generation of artifacts ranging from “no perceptible error” to “multiple block errors” that look like FM threshold sparkles to “freeze frames” or “black screens” for really significant errors.

Reacquisition

Improvements in technology against terrestrial interference focus on two primary areas, reacquisition of the carrier, and concealment. Reacquisition deals with the time it takes to reacquire the carrier, decode and restore video after an RFI “hit” takes place. Reduction of the reacquisition time to its lowest value is the objective in any design consideration.

Concealment

Concealment deals with the methods employed in the IRD as it relates to video presented to the viewing audience during the reacquisition period. Various approaches can be employed, use of a “black screen”, displaying digital artifacts, or freezing the video frame are all methods that can be used to display video during the reacquisition sequence.

Sources of Interference

There are a variety of sources of interference, which can affect a digital compression path. Identification of the interfering source is an important step in the goal of reducing the effects of RF interference on the desired signal.

Interference can have two effects on a digital carrier:

- 1) Compression or saturation of the RF receiving equipment including LNA's, LNB's, line amplifiers, and RF Tuner inside the IRD.
- 2) Direct corruption of the digital carrier.

There are three areas, which need to be addressed in protecting the digital carrier against interfering sources:

1. Protection from saturation or compression in the RF path
2. Error correction and reacquisition of the digital carrier
3. Concealment with regard to the source material displayed to the viewing audience.

The following section details the potential sources of RF Interference.

Terrestrial Microwave Interference

Much of the world's populated areas are utilizing terrestrial microwave signals. These signals range from typically 2 GHz to 15 GHz with a major concentration in the 3.1 GHz to 4.99 GHz band. Terrestrial microwave transmitter/antennas will be located at or near places of commerce, metropolitan areas, near airports, or large industrial facilities. Microwave repeaters may be found at intermediate points *in* the path throughout populated and often times unpopulated regions.

Most terrestrial microwave interference manifests itself as a single modulated or unmodulated carrier, and is readily observable in the C-band pass band of the system with a Spectrum analyzer. A site survey should be performed prior to final location of the earth station to ensure that terrestrial microwave carriers will not be a problem. Microwave interference may require relocation of the satellite-

receiving antenna into a “clear” path. Should the presence of these carriers be detected prior to site location, they can be treated as part of the satellite link analysis to evaluate their affect on performance.

Impulse and Ignition Noise

A digitally compressed video signal can be susceptible to interference from impulse generators. Some typical sources of impulse noise are power equipment (power generators) or ignition noise from engines (vehicles, motorcycles, mopeds, lawn mowers, power blowers). Spark emissions cover a wide band of RF frequencies including C-band and can enter through the satellite dish and LNB. These emissions can originate from engines where broken, intermittent or “arcing” spark plug cables are used. Ignition wires are typically resistive wires that dampen RF radiation, however a broken or intermittent ignition wires can arc and emit excessive radio interference. Ignition “burst noise” can last in excess of 1 millisecond, exceeding the interleave depth of the error correction system designed into the IRD and can have a power level 40 dB higher than the satellite carrier. The repetition rates greater than once every 70 millisecond have been detected.

When planning an earth station you should site the station well away from sources of ignition interference such as busy roads, highways, intersections, or car parks. You may want to restrict the use of gasoline-powered lawn mowers and other combustion engines during peak usage hours.

Because ignition noise represents broadband interference an operator experiencing ignition noise should address both the issue of saturation as well as attempt to reduce the magnitude of the interfering source. To address saturation, attenuators should be utilized both at C-band (if used) and L-band. An interfering carrier from a automobile ignition can be more than 40 dB higher than the receiving signal and saturate LNB's, line amplifiers and the RF tuner in the satellite receiver. Severe ignition noise problems can be addressed by relocation of the receiving antenna, use of an “earth berms”, or installation of an RFI grounded fence between the interfering sources and the earth station antenna.

Aircraft Radar Altimeters/Airport Ground Radar

If your downlink antenna is located near an airport or flight path your system can pick up interfering carriers from aircraft radar altimeters. The radar altimeter Spectrum is 4.200 to 4.400 GHz. This corresponds to 750 to 950 MHz at the L-band output of the LNB. These carriers have been measured in excess of +40dBc relative to the desired satellite carrier. This kind of interference often results in the saturation of any line amplifiers to the extent that the amplitude of the desired Spectrum is reduced below a measurable level. The effects of this interference may last several seconds until the aircraft passes out of the earth station antenna beam. The interference appears as a chirp or energy spread over the indicated Spectrum. It is first observed as a low level signal and gradually builds to its maximum level before gradually diminishing.

These interfering carriers are usually out-of-band and can be dealt with by installing a C-band block filter that can be specifically manufactured for greater protection at the aircraft radar frequency.

Other potential sources of interference from airports are ground looking radar that can saturate LNA/LNB's. Frequency coordination in some countries allow for adjacent bands to be utilized where they can cause out-of-band interference. Once again, C-band band pass or block filters remain an effective means of controlling the interfering carrier.

Ship-board Radar

Another potential source of interference in coastal areas is shipboard naval radar. Usually, this on-board radar is not supposed to be utilized within a radius of the shore; however, there are documented cases where this radar has been "turned on" with deleterious effects to the local coastal viewing audience.

Commercial Microwave Ovens

Commercial microwave ovens operating in fast-food chains and earth station lunchrooms are potential sources of interference. Emissions levels allowed by a microwave oven can be as much as 20 dB higher than a C-band satellite carrier; however, microwave oven manufactures are normally required to replace units that are known to interfere with commercial broadcast systems. A typical operating frequency for a microwave oven is 2250 MHz with a considerable amount of wide band noise generated in the 3900 MHz to 4500 MHz range. This noise can become more apparent over the life of the magnetron and can be prevalent near the end of its useful life.

Walkie-Talkies

Walkie-talkies have been observed to interfere with the operation of IRDs. Operating a walkie-talkie in the vicinity of the IRD can interfere with the operation of the IRD. Restricted use of walkie-talkies is recommended in the vicinity of a downlink earth station.

Cell Phones

Cell (Cellular) Telephones operate in the 900 Mhz range and can directly interfere with the down converted (IF) signal from the LNB to the IRD. The activation of a cell phone unit near the IRD may generate unacceptable destructive or out of band interference which may enter the IRD through poorly shielded cabling or improperly terminated dividers and connectors.

Random RFI (Fluorescent and Sodium Vapor Lamps, Lightning)

Particularly on start-up, fluorescent lamps can flicker causing an interfering source to an earth station antenna nearby. Another potential source is sodium vapor lamps when in a "failed" condition. Lightning is another known source of RFI that can effectively wipeout both digital and analog carriers. Though these sources are not a common occurrence, they should be mentioned in the investigation of a RFI occurrence.

Protection from Interference

Selecting a site

Site selection is the most important pro-active step an earth station operator can take in prevention of terrestrial interference. Busy roads and highways, parking lots, power generators, and power equipment near the receiving antenna are all potential sources of interference. Sites located near airports may need special consideration due to aircraft radar altimeters.

Saturation and Compression

Many traditional earth station operators in the analog environment are concerned with obtaining the highest signal level possible for their analog receiving equipment. High signal levels in the digital environment can be problematic where terrestrial interference is present.

Ignition noise is a common problem where saturation can occur in the RF path. Interfering carriers can potentially be 40 dB higher than the satellite carrier resulting in compression of the RF subsystems.

Optimizing signal levels through the use of C-band and L-band attenuator pads to increase the “headroom” of the system where RFI is found can dramatically improve performance of the receiving equipment. Installation of 6dB and 10dB pads in front of line amplifiers, block down converters, and video receiver/decoders can provide the additional “headroom” needed to prevent saturation during a RFI hit. Operating IRD’s in a “low gain” mode is another useful way to add additional “headroom” for RFI “hits”.

Many earth station operators utilize line amplifiers in traditional analog systems, which can aggravate the effect of RFI and compression. Signals that are spiked due to RFI in combination with a high gain line amplifier can saturate downstream block down converters and RF tuners inside the IRD. Optimization of the RF path, including line amplifiers is necessary when combating RFI.

Out-of-band Filtering

For sites experiencing aircraft radar or out-of-band interference, C-band filtering in front of the LNA/LNB is an effective way to protect from interfering carriers. Special notch filters have been made for aircraft radar that are effective in those specific locations near airports or aircraft approaches.

RFI (Radio Frequency Interference) Fencing

Special RFI fencing can often reduce the source of interfering carriers or ignition noise where it is present. Wire fences of the proper diameter, located between the interfering source and the earth station antenna can be an effective way of dealing with terrestrial interference. Fences that can be utilized for RFI protection can be as simple as fine wire mesh of galvanized steel, properly grounded that roughly meets the desired dimensions of 1/10 wavelength beyond cutoff of the C-band carrier. It is important to install the fence at the proper height and distance.

from the earth station antenna, with special attention being paid to the construction, (galvanized steel is preferred).

A wire mesh fence, properly constructed, will scatter-back and absorb the energy and appear to the interfering signal much like a solid sheet of metal. The optimum dimension for the mesh fencing is a mesh size smaller than 1.27cm, (1/2 inch), which offers adequate protection at C-band.

To block ignition impulse noise from a busy street or parking lot, a galvanized steel fence with a mesh size smaller than 1.27cm (1/2 inch), should be grounded with copper grounding rods or chemical ground system. The wire fence in combination with the ground system should accommodate a wide variation of RF emissions generated from engine ignition systems. Effective fences that have also been utilized in the past are fine wire mesh and solid thin sheet metal barriers.

Earth Berms

A more drastic but very effective manner to protect from terrestrial interference is the use of earth berms. Placing the antenna below ground level, while more costly and not always practical, it still provides an excellent manner in which to protect the integrity of the receiving signal from RFI.

When constructing a "earth berms" careful considerations should be given to the side lobes of the antenna since the noise temperature of the earth is much higher than that of the dark sky. The surrounding earth in the earth berms may cause a noise figure degradation if it is not significantly outside of the antenna side lobe.

Summary

Digital Video Compression systems will continue to be the choice for future satellite video broadcasting because of the bandwidth efficiency and unsurpassed video quality. The traditional FM analog approach to earth station operation will enter a new era with the advent of video compression. Many video earth station operators are learning the same sensitivities to RFI as the traditional digital common carriers (IDR) networks used in the telecommunications industry. Through education of earth station operators, adaptation to the environment, and advances in technology, digital compression systems will become the standard in satellite video broadcast delivery throughout the world. Education and understanding of the effects of terrestrial interference, and its prevention, are the most important steps in achieving the high standard of service demanded by subscribers in the worldwide marketplace.

Table 4-1 Spectrum Analyzer Setup
<ol style="list-style-type: none"> 1. Connect the input of the spectrum analyzer with a T-connector between the LNB and the receiver. Caution: This will put 13-19 volts DC on the input of the spectrum analyzer and could damage it. To prevent this from happening use a DC blocker on

<p>the input of the analyzer while still feeding the LNB with the required receiver DC voltage. This will allow you see spectrum plot for the signal you intend to capture.</p> <p>2. Set the frequency to satellite L-band frequency between 950 MHz and 1450 MHz.</p> <p>3. Span to 100 MHz.</p> <p>4. Amplitude to -45 dB</p> <p>5. Vertical scale to 1 dB per scale. If signal is out of range adjust accordingly</p>

Table 4-2 Typical Satellite Receiver Setup	
9234	9223
a. Freq. Mode	a. Band
b. Frequency	b. L-band Freq
c. Polarization	c. Polarization
d. FEC Rate	d. FEC Rate
e. Symbol Rate	e. Symbol Rate
f. L.O. Freq	f. L.O. Freq
g. Video Standard (NTSC)	g. Video Standard (NTSC)

Table 4-3 Bit Error Rate (BER) to Threshold Margin Table		
Bit Error Rate Reading	SatNet FEC $\frac{3}{4}$	DTS FEC $\frac{2}{3}$
2.00E-02	--	0.22
1.00E-02	0.36	1.44
5.00E-03	1.36	2.36
2.00E-03	2.38	3.36
1.00E-03	3.12	4.10
5.00E-04	3.78	4.76
2.00E-04	4.56	5.54
1.00E-04	5.08	6.10
5.00E-05	5.58	6.60
2.00E-05	6.14	7.12
1.00E-05	6.50	7.48
5.00E-06	6.78	7.78
2.00E-06	7.18	8.18
1.00E-06	7.42	8.46

Note: The information shown is the amount of margin, in dB, over the DVB specification threshold for a given BER display. For example, a BER reading of 5.00E – 04 on a SATNET decoder provides 3.78 dB of margin over the Eb/No threshold of 5.5 dB or a total Eb/No of 9.28 dB. At the same BER, DTS provides 4.76 dB of margin over the Eb/No threshold of 5.0 dB for a total Eb/No of 9.76 dB.

Scientific Atlanta developed the table from actual testing of decoders over a range of symbol rates. The standard deviation is 0.2 dB.